Davis Soil Moisture and Temperature Station Protocol

Purpose

To log soil data using a Davis soil moisture and temperature station

Overview

Soil moisture and temperature sensors are installed at multiple depths and a station is set up to measure and record measurements at 15 minute intervals. These measurements are transferred to your school's computer and then submitted to GLOBE via email data entry. Gravimetric soil moisture measurements must be taken to develop calibration curves for the soil moisture sensors.

Student Outcomes

Students can view data for their soil that are continuous and show variations within a day. This enables detailed study of soil moisture and temperature variations with time and depth.

Science Concepts and Scientific Inquiry Abilities

Science Concepts and *Scientific Inquiry Abilities* are gained through analyzing the data collected with the weather station. Refer to the *Gravimetric Soil Moisture* and *Soil Temperature Protocols* for the Science Concepts and Scientific Inquiry Abilities listed in their gray boxes.

Time

2 hours for site definition and set-up

Initial calibration requires doing the *Gravimetric Soil Moisture Protocol* for at least the 30 cm depth about 15 times over six or more weeks. This will take 15 - 45 minutes each time.

15 minutes to use email data entry to prepare and submit data to GLOBE periodically.

Level

Middle and Secondary

Frequency

Data reporting approximately once every week

Soil moisture sensor replacement and calibration every two years

Materials and Tools

- Soil moisture and temperature station and a weather station with data logger
- Computer capable of running weather station software
- Appropriate soil auger
- Meter stick
- Four soil moisture sensors
- 4-L soil holding/mixing buckets Water for making mud balls (0.5 L)
- One 120 cm x 2 cm PVC guide tube
- Soil packing stick (e.g. an old broom handle)
- Pen or pencil
- Calculator and graph paper or computer
- *Biannual Soil Moisture Sensor Calibration Data Sheet*
- Materials for the *Gravimetric Soil Moisture Protocol*

Preparation

Set up the soil moisture and temperature station.

Prerequisites

Gravimetric Soil Moisture Protocol

Automated Soil Moisture and Temperature Stations – Introduction

Using automated soil moisture and temperature stations that record data can allow students to take soil measurements at much shorter time intervals than collecting data by hand. The large volume of data that can be collected allows for detailed study of soil conditions, including hourly variations, which are often significant near the surface.

The soil moisture and temperature stations used in this protocol are manufactured by Davis Instruments (http://davisnet.com). These soil moisture and temperature stations connect to weather stations that have a display screen that shows current soil conditions. Atmospheric sensors may also be connected to the weather station to collect atmospheric data as outlined in the *Davis Weather Station Protocol.*

Besides displaying current readings on the display screen, the weather station also records data over a long period of time using a data logger. This data logger is sold in a kit that also includes software that lets you download the data onto your computer and visualize it and is required for this protocol. The same software works for both the atmosphere and soil measurements, so if you are doing both, only one data logger and software package is needed.

Once the data are downloaded from the weather station to your computer, you can export it to a text file, ingest it to a spreadsheet program, and manipulate it to conform to the format required for GLOBE email data entry. Software is available for some models to export text files in GLOBE's email data entry format.

Teacher Support

The instructions given in this protocol are specific to one brand of soil moisture and temperature station. However, they may be adapted to other equipment that meets the same specifications. If you have questions or require assistance with adapting these instructions to other instruments, contact your Country Coordinator or, in the US, the GLOBE Help Desk. The essential elements of this protocol, which must remain the same regardless of the equipment model, are the placement of the station and sensors, the precision and accuracy of the sensors, and the sampling interval.

The soil moisture and temperature station reports soil moisture readings in units that correspond to centibars of water tension. To interpret these readings correctly in terms of soil water content (grams water/grams dry soil), it is necessary to construct a calibration curve. Once constructed, this curve is used to convert the meter readings to soil water content and both are reported to GLOBE. Details of the process for creating this curve are given in the *Soil Moisture Calibration Procedure* section below.

You may wish to collect data with your soil moisture and temperature station at an existing Atmosphere Study Site or Soil Moisture Study Site. This will make the data collected with the soil moisture and temperature station more readily comparable to other GLOBE measurements being taken at these sites. However, you also may choose to define a new site specifically for your soil moisture and temperature station. If so, please define this new site following the *Soil Moisture Site Definition Data Sheet*. If your station is not collocated with a device measuring current air temperature, an air temperature sensor may be added to your three soil temperature sensors provided you install an instrument shelter in which to mount this sensor.

Data Recording

The GLOBE database requires soil station data logged at 15-minute intervals, so make sure that the sampling interval for your station is set to 15 minutes. Also, the read-out should happen

on the quarter-hour (e.g., 10:00, 10:15, 10:30, 10:45, etc.) Ensure that measurements are being displayed and reported in degrees Celsius for temperature. Soil moisture should be displayed in units from 0 (wet) to 200 (dry).

Due to the quantity of data involved, soil moisture and temperature station data are reported to GLOBE only via email data entry. Software provided by Davis may allow data to be exported directly into the correct GLOBE email data entry format (see *Frequently Asked Questions* for information on the availability of this software). Use the "Export Records (GLOBE Format)" option from the Browse menu option in the export data pull-down menu. If you are using your weather station to record atmospheric data, then this atmospheric data will be exported at the same time. If the software for your weather station does not have this option, export your data to a text file, import the text file into a spreadsheet program, manipulate the columns to match the requirements for email data entry, and cut and paste the resulting lines of data into an email data entry message.

The time associated with each data point reported to GLOBE needs to be in Universal Time (UT). If you choose to have your weather station set to local time, you will need to make sure that you adjust the times reported to GLOBE. Some software packages will make this change for you automatically when outputting data in GLOBE email data entry format.

Measurement Logistics

1. Review background in the *Introduction* of the *Soil Temperature* and *Gravimetric Soil Moisture Protocols.*
2. Setup the weather station console and connect to your computer according to manufacturer's directions.
3. Install the temperature sensors according to the *Installation of Temperature Sensors Field Guide*.
4. Install soil moisture sensors according to the *Installation of Soil Moisture Sensors Field Guide*.
5. Log readings at 15-minute intervals and transfer data to your computer according to the directions included with your software.
6. When you are ready to report the data to GLOBE (recommended once a week) export the data stored in your computer to a text file in the format for GLOBE email reporting following the *Logging and Reporting Soil Moisture and Temperature Station Data Lab Guide.*
7. Paste the text in this file into the body of an email. Send it to GLOBE following email data entry instructions available in the "Data Entry" section of the GLOBE Web site.
8. Collect gravimetric soil moisture readings following the *Collecting Soil Moisture Sensor Calibration Data Field Guide*.
9. As you collect gravimetric soil moisture readings report these data to GLOBE, and once you have about 15 calibration points, GLOBE will create a calibration curve for you. Students may follow the *Creating a Calibration Curve Lab Guide* and create a calibration curve for themselves.
10. Engage students in looking at the data.
11. Every two years, replace the soil moisture sensors and take new gravimetric soil moisture data to create your new calibration curve.

Soil Moisture Calibration Procedure

The soil moisture and temperature station reports soil moisture readings that correspond to centibars of water tension on a scale of 0-200. To be useful to the GLOBE science community they need to be in terms of soil water content (grams water/grams dry soil). The procedures for collecting calibration data and creating a calibration curve are the same as those given in the *Soil Moisture Sensors Protocol* for Watermark meters.

Every two years students need to install new Watermark soil moisture sensors and calibrate them.

Helpful Hints

- The day before you plan to install your sensors, place the soil moisture sensors in a bucket of water.
- When looking for a location to install your soil moisture and temperature station, be sure to account for the need for the station to communicate with your weather station.

Questions for Further Investigation

Which season has the greatest range of soil temperatures? Why?

What are the latitudes and elevations of other GLOBE schools with soil moisture and temperature patterns similar to yours?

Does soil temperature at 5 cm correlate strongly with air temperature or with surface temperature? At 10 cm? At 50 cm?

Is there a relationship between soil moisture and the time of budburst?

How long does it take for a precipitation event to affect soil moisture readings at various depths? Does precipitation affect soil temperature?

Installation of Soil Moisture Sensors

Field Guide

Task

To install the soil moisture sensors

What You Need

- ❑ Soil Auger
- ❑ Meter stick
- ❑ Soil Moisture and Temperature Station with 4 Watermark Soil Moisture Sensors
- ❑ 4-L soil holding/mixing buckets
- ❑ One 120 cm x 2 cm PVC or other tube for protecting wires
- ❑ Water for moistening the soil (0.5 L)
- ❑ One 1 m x 2 cm PVC guide tube
- ❑ Soil packing stick (e.g. an old broom handle)
- ❑ Permanent marker

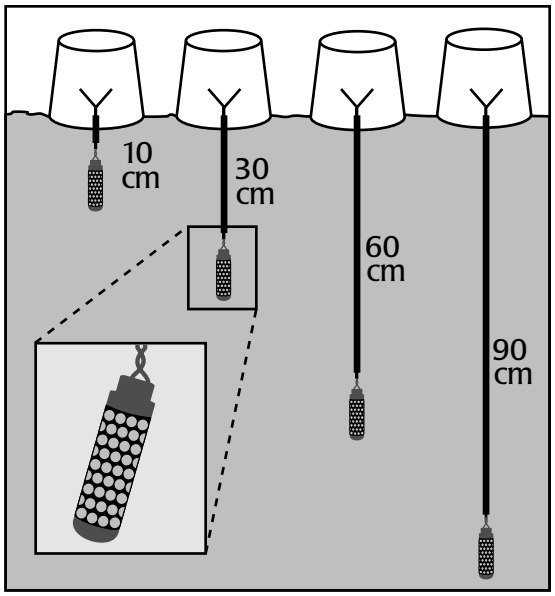
In the Field

1. Place the sensors in water and **soak overnight.**
2. Use a permanent marker to place marks on the sensor cables near the contacts. Use 1 line drawn completely around the cable for the 10 cm sensor. Use 2 lines for 30 cm, 3 lines for 60 cm, and 4 lines for 90 cm.
3. Auger a hole to the appropriate depth for the soil moisture sensor (10 cm, 30 cm, 60 cm or 90 cm). Each sensor will go in its own hole. Make sure the cable can reach the Soil Moisture and Temperature Station with some slack.
4. Place two large handfuls of soil extracted from the bottom of each hole into a small bucket or similar container. Remove any rocks. Add a small amount of water and stir to create soil that is moist enough that it stays together when pressed into a ball.
5. Drop the moist soil ball to the bottom of the hole. Make sure it reaches the bottom.
6. Push the wire lead from one of the sensors through the PVC guide tube.
7. Pull the end of the wire lead until the sensor fits firmly against the other end of the guide tube. Lower the tube into the hole with the sensor going in first. While holding the wire lead at the top of the pipe, gently push the tube down until the sensor is set into the moist soil at the bottom of the hole.
8. Hold the sensor in place with the guide tube while you begin to backfill the hole. As you slowly add soil to the hole, gently pack or tamp it with a broom handle or similar pole. After the sensor is covered, remove the guide tube. Continue adding soil a few handfuls at a time and tamping firmly as you backfill the hole. Hold on to the wire lead as you backfill so that it will come straight to the surface.

9. Feed the wire through the protective PVC or other tube.
10. Repeat steps 2-9 for each sensor.
11. Connect the leads to the Soil Moisture and Temperature Station. The 10 cm sensor is connected to channel 1, 30 cm to channel 2, 60 cm to channel 3, and 90 cm to channel 4.

Note: Do not report measurements for a week after installation. The sensors require at least one week to equilibrate to natural conditions. The wire leads are fragile, especially where they connect to the meter. If the end of the wire leads to the soil moisture sensors break, peel back the wire insulation and make new leads.

Installed Soil Moisture Sensor Configuration



Installation of Temperature Sensors

Field Guide

Task

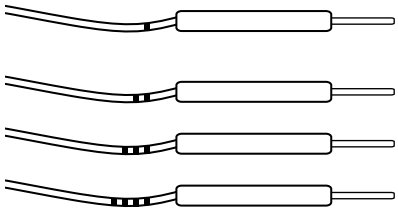
Install the soil temperature sensors of your soil moisture and temperature station.

Note: The following is written for an installation involving four temperature sensors, with one sensor used to measure air temperature and three sensors used to measure soil temperature at specified depths. If your soil moisture and temperature station is located at a site that has another instrument taking air temperature measurements, you may choose to omit the sensor for air temperature. If you choose not take air temperature readings, it is important that the sensors for soil temperature are still plugged into channels 2-4 of the Soil Moisture and Temperature Station.

What You Need

- ❑ Meter stick
- ❑ Digging tools
- ❑ Properly installed instrument shelter and 4th temperature sensor for air temperature (optional)
- ❑ Soil Moisture and Temperature Station with 3 temperature sensors
- ❑ One 120 cm x 2 cm PVC or other tube for protecting wires (may be same as for soil moisture sensor wires)
- ❑ String or wire ties
- ❑ Permanent marker

In the Field



1. Choose a location where the soil moisture and temperature station will be protected. If you have an instrument shelter you may choose to mount the soil moisture and temperature station on the pole. If you are using a wireless soil moisture and temperature station, make sure that it can communicate with your weather station from the chosen location.
2. Plug the temperature sensors into the soil moisture and temperature station. Use a permanent marker to place marks on the end of each cable about 1 cm from the sensor. Use 1,2,3 or 4 lines drawn completely around each cable, corresponding to the channel of the soil moisture and temperature station into which the cable is plugged. Feed the sensors through the PVC or other tube to protect them.
3. If you are taking air temperature measurements, use string or a wire tie to secure the air temperature sensor (#1) inside the instrument shelter, taking care that it does not contact the sides of the shelter.
4. Sensors # 2-4 will be used to measure soil temperatures. Dig a 50 cm deep hole close enough to the location of your Soil Moisture/Temperature Station that the sensors will reach. If you are digging near any obstructions, make sure to locate the hole on the sunny (equatorward) side of the obstructions.
5. Push the soil temperature sensors horizontally into this hole at depths of 50 cm (#4), 10 cm (#3), and 5 cm (#2). Use a nail or pin to pilot these holes if the soil is firm or extra firm.
6. Refill the hole with the soil that you removed (last out, first in).

Determining Soil Uniformity With Depth

Field and Lab Guide

Task

Determine whether the soil particle density and texture are uniform at 10 cm, 30 cm, 60 cm, and 90 cm depths

What You Need

- ❑ Soil auger
- ❑ Meter stick
- ❑ Four soil containers (bags or soil moisture sample cans)
- ❑ Materials for the *Soil Particle Density Protocol*
- ❑ Materials for the *Particle Size Distribution Protocol*
- ❑ Soil drying oven

A calibration curve for your soil moisture sensor at 30 cm depth must be developed for conversion from meter readings to soil water content. There is no need to develop calibration curves for other depths unless they differ significantly in soil particle density or texture. The following steps are how you determine this.

In the Field

1. Near the holes where your soil moisture sensors are installed, use the auger to take samples from 10 cm, 30 cm, 60 cm, and 90 cm depths and store them for lab analysis. Samples should be at least 200 g each. Labels should give the date and depth.
   Note: If you are using these samples for the *Gravimetric Soil Moisture Protocol*, follow the steps of that protocol for taking, storing, weighing, and drying the samples, and then, use the dry samples in the steps given below beginning with step 4.

2. Replace the remaining soil in the hole with soil from the deepest depth going in first and soil from near surface going in last.

In the Lab

3. Dry your soil samples.
4. Determine the soil particle density of each sample following the *Soil Particle Density Protocol*.
5. Determine the texture of each sample following the *Particle Size Distribution Protocol*.
6. Compare the particle densities at 10 cm, 60 cm, and 90 cm, with the value at 30 cm. If the value for a depth differs by more than 20% from the density at 30 cm, you should produce a separate calibration curve for that depth.
7. Locate the textures at the four depths on the *Soil Texture Triangle*. If the texture at 10 cm, 60 cm or 90 cm depth is not in the same area on the Triangle as the texture at 30 cm depth or if it is not in an area bordering the texture at 30 cm depth on the *Triangle*, produce a separate calibration curve for that depth.
8. You may wish to return your samples to the appropriate depths when you take samples for building your calibration curve.

Calibration of Soil Moisture Sensors

Field Guide

Task

To calibrate the soil moisture sensors.

What You Need

- ❑ Soil Auger
- ❑ Meter stick
- ❑ Pen or pencil
- ❑ Properly installed soil moisture sensors
- ❑ Soil moisture meter
- ❑ Materials for the *Gravimetric Soil Moisture Protocol* (i.e., cans, oven, trowel, marking pen)
- ❑ *Biannual Soil Moisture Sensor Calibration Data Sheet(s)*

In the Field

1. Complete the top portion of your *Biannual Soil Moisture Sensor Calibration Data Sheet*.
2. Record the soil moisture reading from your computer for the date and time of your gravimetric sample in column G, Soil Moisture Meter Reading, of the *Biannual Soil Moisture Sensor Calibration Data Sheet(s)*.
3. Select a random location within 5 m of the sensor holes.
4. Clear away any surface debris.
5. Use the auger to collect samples for the *Gravimetric Soil Moisture Protocol* from each depth for which you are developing a calibration curve. Place each soil sample in a container and number the container.
6. Backfill the hole (last out, first in) and replace the surface cover.
7. Record the date, time, depth(s) and container number(s) in your science notebooks.
8. Determine the soil water content of each sample following the *Gravimetric Soil Moisture Protocol Lab Guide*.
9. Record the date and time of your measurement, the wet, dry, and container weights on the *Biannual Soil Moisture Sensor Calibration Data Sheet*. Calculate the water mass, dry soil mass and soil water content and record their values on the *Data Sheet*.
10. Report your gravimetric soil moisture data to GLOBE.
11. Repeat steps 2 – 10 about fourteen times as the soil moves through one or two complete drying cycles. Wait until your meter reading changes significantly before collecting another gravimetric sample.
12. Report your calibration data to GLOBE and a calibration curve will be created, used to convert your meter readings to soil water content and sent to your school.

Creating a Calibration Curve - Watermark Meter

Lab Guide

Task

To create a calibration curve

What You Need

❑ Pen or pencil

❑ Graph paper or appropriate spreadsheet graphing software

❑ *Biannual Soil Moisture Sensor Calibration Data Sheet* with 15 or more pairs of readings for each depth for which you are developing a calibration curve

❑ Calculator or computer

In the Lab

1. Plot all the pairs of readings for a single depth with soil water content on the Y-axis and the corresponding soil moisture meter readings on the X-axis. This can be done using spreadsheet software.

2. Draw or calculate the *best-fit natural logarithmic curve* through your data points.

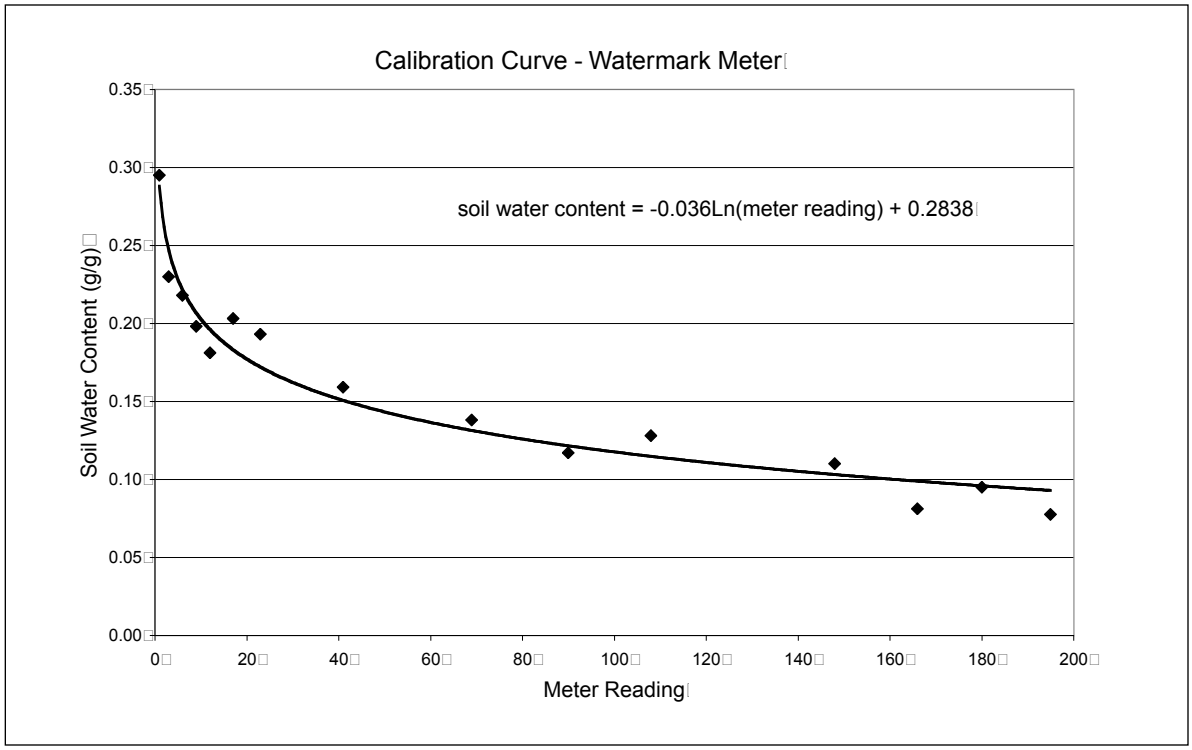
   $$\text{Soil Water Content} = a \ln(\text{Soil Moisture Reading}) + b$$

   Your data should span a broad range of soil moistures. This will be your calibration curve, which you will use to convert your meter readings to soil water content values.

   Note: If you have any questions about creating your calibration curve or if you need any assistance with the curve, contact the GLOBE Help Desk or your country coordinator and ask for help from the appropriate GLOBE scientist.

3. Mail or email a copy of your curve and of your corresponding *Biannual Soil Moisture Sensor Calibration Data Sheet* to GLOBE following the directions for submitting maps and photos given in the *How to Submit Photos and Maps* section of the *Appendix* of the *Implementation Guide*. If while taking soil moisture measurements you get meter readings either higher or lower than any of the readings on your data sheet, take a gravimetric sample, and use the values you measure for this sample to extend your calibration curve. Send a copy of your revised calibration curve and extended *Biannual Soil Moisture Sensor Calibration Data Sheet* to GLOBE.

Example of a Soil Moisture Sensor Calibration Curve for a Watermark



Logging and Reporting Soil Moisture/Temperature Station Data

Lab Guide

Task

Log and report data collected with your Soil Moisture/Temperature Station.

What You Need

- ❑ A setup and operating soil moisture and temperature station connected to a weather station.
- ❑ A suitable computer with email access.

In the Field

1. Set your weather station to log data at 15 minute intervals on the quarter hour (e.g., 15:15).
2. Download your soil moisture and temperature station data (and any atmospheric data taken following the *Davis Weather Station Protocol*) to your computer following the instructions for your weather station.

   Note: some weather stations can be set-up to transfer these data automatically
3. Export a text file of your data. Save this file on your computer. (If your software has the ability to export a text file in the GLOBE email data entry format, skip to step 5).
4. Use spreadsheet or other software to edit the exported file into the GLOBE email data entry format. Save this spreadsheet file on your computer.
5. Copy and paste your data in GLOBE email data entry format into the body of a GLOBE data entry message.

Frequently Asked Questions

1. The soil particle density and texture differs at the different depths at our site. How many calibration curves must we develop?

All depths with similar soil particle densities (within 20%) and textures (the same or adjacent on the *Soil Texture Triangle*) may share the same calibration curve.

The following table describes seven possible situations and states what calibrations curves should be developed and how they should be used.

Situation	What to do
Each depth is different from all the others	Develop individual calibration curves for each depth.
30 cm, 60 cm, and 90 cm are similar but 10 cm is different	Develop a calibration curve for 10 cm and use it for 10 cm and develop a separate curve for 30 cm and use it for 30 cm, 60 cm, and 90 cm.
10 cm, 30 cm, and 60 cm are similar but 90 cm is different	Develop a calibration curve for 90 cm and use it for 90 cm and develop a separate curve for 30 cm and use it for 10 cm, 30 cm, and 60 cm.
10 cm and 30 cm are similar, 60 cm and 90 cm are similar but different from 10 cm and 30 cm	Develop a calibration curve for 30 cm and use it for 10 cm and 30 cm; develop a separate curve for 60 cm and use it for 60 cm and 90 cm.
30 cm and 60 cm are similar, but 10 cm and 90 cm differ from one another and from 30 cm and 60 cm	Develop separate calibration curves for 10 cm, 30 cm, and 90 cm; use the 30 cm curve for 30 cm and 60 cm.
10 cm and 30 cm are similar, but 60 cm and 90 cm differ from one another and from 10 cm and 30 cm	Develop separate calibration curves for 30 cm, 60 cm, and 90 cm; use the 30 cm curve for 10 cm and 30 cm.
60 cm and 90 cm are similar, but 10 cm and 30 cm differ from one another and from 60 cm and 90 cm	Develop separate calibration curves for 10 cm, 30 cm, and 60 cm; use the 60 cm curve for 60 cm and 90 cm.

Soil Investigation

Biannual Soil Moisture Sensor Calibration Data Sheet

School Name: _____

Study Site:_____

Drying Method (check one): 95-105 °C oven ___; 75-95 °C oven ___; microwave____

Average Drying Time: _____ (hours or minutes)

Depth (Check one): ❑ 10 cm ❑ 30 cm ❑ 60 cm ❑ 90 cm

Observations:

Measurement											
#	Date	Local Time Hour:min	Time (UT)	Observers' Names	A. Wet Mass (g)	B. Dry Mass (g)	C. Water Mass (A-B)	D. Can Mass (g)	E. Dry Soil Mass (B-D)	F. Soil Water Content (C/E) Reading	G. Soil Moisture Meter Reading
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											

Soil Investigation

Biannual Soil Moisture Sensor Calibration Data Sheet – Continued

School Name: _____

Study Site:_____

Depth (Check one): ❑ 10 cm ❑ 30 cm ❑ 60 cm ❑ 90 cm

Observations:

Measurement											
#	Date	Local Time Hour:min	Time (UT)	Observers' Names	A. Wet Mass (g)	B. Dry Mass (g)	C. Water Mass (A-B)	D. Can Mass (g)	E. Dry Soil Mass (B-D)	F. Soil Water Content (C/E) Reading	G. Soil Moisture Meter Reading
11											
12											
13											
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